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## (54) Gas generator for air bag and air bag system

(57) To provide a gas generator for an air bag which enables a gas generating agent to be completely burned in a desired period of time, and shows sufficient operating characteristics.

In a gas generator for an air bag wherein igniting means to be actuated when an impact sensor detects an impact, solid bodies of gas generating agent to be ignited by the igniting means and burned to generate a combustion gas, and filter means for cooling the combustion gas and scavenging combustion residues are accommodating in a housing having gas discharge ports, the ratio (A/At) of the total surface area A of the solid bodies of gas generating agent to the total opening area At of the gas discharge ports is controlled to be larger than 300.

EP 0 876 943 A2

**Description****[Detailed Description of the Invention]****[Field of the Invention]**

The present invention relates to a gas generator for an air bag for protecting a passenger from an impact, and an air bag system. In particular, this invention is concerned with a gas generator for an air bag wherein the ratio (A/At) of the total surface area A of solid bodies of gas generating agent contained in a housing to the total opening area At of gas discharge ports formed through the housing is controlled to a specified range.

**[Description of the Prior Art]**

In a conventional gas generator for an air bag, igniting means to be actuated when an impact sensor detects an impact, a gas generating agent to be ignited by the igniting means and burned to generate combustion gas, and filter means for cooling the combustion gas and/or scavenging combustion residues are accommodated in a housing having gas discharge ports. In this type of gas generator, when the igniting means is actuated upon detection of an impact, the gas generating agent is ignited and burned to generate combustion gas. The combustion gas is cooled and purified by the filter means in the housing, and discharged out of the housing through the gas discharge ports. Gas generating agents used for generating the combustion gas may be roughly classified into azide-containing gas generating agents, and other gas generating agent containing no azide.

The azide-containing gas generating agent (such as  $\text{NaN}_3/\text{CuO}$ ) has a relatively high linear burning velocity, for example, about 45 - 50 mm/sec under a pressure of 70 kg/cm<sup>2</sup>. Accordingly, even when the gas generating agent is formed into a relatively large pellet-like shape or disc-like shape that can be maintained with high stability, the gas generating pellets or discs may be completely burned in a desired period of time, i.e., 40 to 60 msec, when used in the gas generator for an air bag installed on the side of a driver seat, for example.

On the other hand, the non-azide gas generating agent generally has a linear burning speed of 30 mm/sec or lower. If this gas generating agent is formed into a pellet-like shape with a diameter of 2 mm, or a disc-like shape with a thickness of 2mm, for example, the shape of the gas generating pellet or disc can be maintained with high stability, but it takes as much as about 100 msec to burn the gas generating agent where its linear burning velocity is about 20 mm/sec, which is longer than a desired burning time of 40 to 60 msec. Where the linear burning velocity is around 20 mm/sec, the diameter of the gas generating pellet or the thickness of the gas generating disc must be controlled to be around 1 mm so as to achieve a desired burning time.

Where the linear burning velocity is 10 mm/sec or lower, the thickness of the gas generating pellet or disc must be reduced to 0.5 mm or smaller. It is, however, practically impossible to produce pellets or discs of the gas generating agent having such diameter or thickness, which can withstand vibrations of an automobile for a long period of time, while being held in an industrially stable condition. The gas generator containing such gas generating pellets or discs does not perform its functions satisfactorily. Thus, it has been difficult to develop a gas generator that contains a non-aside gas generating agent and can be advantageously used in practical applications.

**[Summary of the Invention]**

It is therefore an object of the present invention to provide a gas generator for an air bag which permits its gas generating agent to be completely burned within a desired period of time, and shows satisfactory operating characteristics.

Since the maximum pressure in the housing upon actuation of the gas generator varies with the temperature of the outside air or atmosphere, it is difficult to provide a gas generator for an air bag which exhibits stable operating characteristics, and does not substantially depend upon the temperature of the atmosphere.

It is therefore another object of the present invention to provide a gas generator for an air bag which is available at a reduced manufacturing cost, and which is able to operate with high stability, without depending upon the temperature of the atmosphere.

The gas generator for an air bag according to the present invention is characterized in that the ratio (A/At) of the total surface area A of solid bodies of gas generating agent stored in a housing to the total opening area At of gas discharge ports formed through the housing is controlled to a specified range.

More specifically, in the gas generator for an air bag of the present invention wherein igniting means that is actuated when an impact sensor detects an impact, a gas generating agent that is ignited by the igniting means and burned to generate combustion gas, and filter means for cooling the combustion gas and scavenging combustion residues are accommodated in a housing having gas discharge ports, the ratio (A/At) of the total surface area A of solid bodies of the gas generating agent to the total opening area At of the gas discharge ports is controlled to be larger than 300.

With the ratio (A/At) of the total surface area A of the gas generating agent to the total opening area At of the gas discharge ports being controlled to be larger than 300, a difference between the maximum output pressures at 85°C and 20°C and a difference between the maximum output pressures at 20°C and -40°C in tank pressure tests using a tank whose capacity is 60 l may be each respectively 25 % or less of the maximum output pressure in the tank test at 20°C. Particularly, the

difference between the maximum output pressures is preferably not higher than 40kPa. In the gas generator for an air bag to be used for a driver seat and a passenger seat, the ratio (A/At) of the total surface area A of the gas generating agent to the total opening area At of the gas discharge ports may be controlled to be larger than 300 but not larger than 1300, and preferably controlled to be in a range of 450 to 1300, more preferably, in a range of 450 to 1000.

In the invention A/At essentially depends on gas-discharging ports and a gas generating agent. No other factor can be taken in account. It is proposed that the inflator of the invention should be necessarily designed and worked with no other means, installed in the inflator, having any substantial influence on A/At. For example, it may be proposed not to place a member of a large resistance-having member upstream before parts which will choke the flow of the gas and control the internal burning (combusting) pressure.

For example, as explained also in the below described embodiments, a coolant/filter is in general placed before controlling means of the burning pressure, i.e. the gas discharge ports, in order to cool the generated gas and scavenge (trap) solid residues of the gas.

The coolant/filter is made by forming a porous mesh member from a metallic wire so that the gas may pass through the inside of the member and the coolant/filter may exhibit the above shown functions. The physical contact between the generated gas and the coolant/filter causes heat-exchanging and collecting of residues as well as produces resistance to the gas flow at the same time. A similar flow resistance appears also at the gas discharge ports controlling the internal burning pressure. When the flow resistance of the coolant/filter is lower than that of the gas discharge ports, the ratio A/At can be designed and determined accurately as described above at the time of installing the coolant/filter.

The flow resistance of the gas discharge ports has an interrelation to their open area. Then the flow resistance of the coolant/filter has an interrelation to the area where the gas passes. An example of these interrelations will be described later.

The air bag gas generator for the driver seat described above has a suitable structure to install on the driver side, for example, in a steering wheel, etc.. That is, the air bag gas generator for the driver seat is a gas generator used for air bag system to protect the driver by activation of the air bag system. On the other hand, the air bag gas generator for the passenger seat, for example next to the drive in the front seat has a suitable structure to install on the passenger side, for example, in the vicinity of a dashboard etc.. That is, the air bag gas generator for the passenger seat is a gas generator used for air bag system to protect the passenger on the passenger side by activation of the air bag system.

The above-indicated housing may be formed by

casting or forging, or may be formed by pressing a diffuser shell having gas discharge ports through which the gas generated by burning the gas generating agent is discharged, and a closure shell having a central aperture in which the igniting means is disposed, and joining these shells together by various welding methods, such as plasma welding, friction welding, projection welding, electron beam welding, laser welding and TIG welding. The housing thus formed by press working can be easily manufactured at a reduced cost. Each of the diffuser shell and closure shell may be formed from a stainless steel sheet having a thickness of 1.2 to 3.0 mm, for example. The volume content of the housing is desirably in the range of 60 to 130 cc for an air bag gas generator of the driver seat and 150 to 600 cc for an air bag gas generator of the passenger seat. The gas discharge ports formed through this housing are desirably circular holes having an inside diameter of 2 to 5mm, and the total opening area of these discharge ports is desirably in a range of 50 to 200 mm<sup>2</sup> where the gas generator is used for an air bag for a driver seat, and in a range of 60 to 500 mm<sup>2</sup> where the gas generator is used for an air bag for a passenger seat.

The gas discharge ports of the housing are preferably closed by an aluminum tape having a width that is 2 to 3.5 times the diameter of each discharge port, for inhibiting entry of moisture from the exterior space into the housing. The aluminum tape may be an adhesive aluminum tape, or may be attached to the housing by means of various kinds of adhesives, such as those that are fused by heat to provide secure bonding. For example, a hot melt adhesive may be used to attach the aluminum tape to the housing.

The gas generating agent is more effectively used in the present gas generator particularly when its linear burning velocity is in the range of 7 to 30 mm/sec, preferably 7 to 15 mm/sec, under a pressure of 70 kg/cm<sup>2</sup>. The gas generating agent having such a property may be a non-azide gas generating agent containing a nitrogen containing organic compound, an oxidizing agent, and a slag-forming agent, for example. The content of the nitrogen-containing organic compound in the gas generating agent may be in the range of 25 to 60% by weight, and the content of the oxidizing agent may be in the range of 40 to 65% by weight, while the content of the slag-forming agent may be in the range of 1 to 20% by weight.

The nitrogen-containing organic compound serves as a fuel and a nitrogen source. Such a nitrogen containing compound may be selected from those containing tetrazole, triazole, or a nitrogen containing organic compound of these metallic salts or the like, and an oxygen containing oxidizing agent, such as alkali metal nitrate, as major components, and triaminoguanidine nitrate, carbohydrazide, nitroguanidine and others. In the present invention, nitroguanidine is particularly preferred. The content of the nitrogen containing compound in the gas generating agent may be generally in

the range of 25% to 60% by weight, preferably, in the range of 30 to 40% by weight, though it varies depending upon the number of carbon elements, hydrogen elements and other oxidized elements in its molecular formula. Although the absolute value of the content of the nitrogen containing compound differs depending upon the type of the oxidizing agent used, minor CO concentration in the generated gas increases as the absolute value is larger than the complete oxidation theoretical value, and minor NO<sub>x</sub> concentration in the generated gas increases as the absolute value is equal to or smaller than the complete oxidation theoretical value. Accordingly, the content of the nitrogen containing compound is most preferably controlled in the range in which these concentrations are optimally balanced.

The slag-forming agent in the gas generating composition functions to convert a liquid form of an oxide of alkali metal or alkali earth metal particularly produced by decomposition of the oxidizing agent in the gas generating composition, into a solid form, so as to retain the oxide in the combustion chamber and thus prevent the oxide in the form of mist from being discharged out of the inflator. The optimum slag-forming agent may be selected to be suited for the metallic component to be converted into the solid form. The slag-forming agent may be formed of at least one kind selected from natural clays containing aminosilicate as a major component, such as those of bentonite and kaolin, and artificial clays, such as synthetic mica, synthetic kaolinite, and synthetic smectite, and talc as one kind of minerals of water-containing magnesium silicate. In the present invention, acid clay may be preferably used as the slag-forming agent. The content of the slag-forming agent in the gas generating agent may vary from 1 to 20% by weight, and is preferably in the range of 3 to 7% by weight. If the content of the slag-forming agent is too large, the linear burning velocity is reduced, with a result of reduction in the gas generating efficiency. If the content is too small, the slag-forming agent cannot sufficiently fulfill its slag-forming function.

The oxidizing agent may be selected from nitrates of alkali metals or alkali earth metals, chlorates, and perchlorates, as well known in the art. In particular, the oxidizing agent preferably comprises at least one kind selected from nitrates of alkali metals or alkali earth metals, which contain cation. For example, strontium nitrate is preferably used. Although the absolute value of the content of the oxidizing agent in the gas generating agent varies depending upon the kind and amount of the gas generating compound used, it is preferably in the range of 40 to 65% by weight, in particular, in the range of 45 to 60% by weight in view of the CO and NO<sub>x</sub> concentrations as described above.

Therefore, in the present invention, a non-azide gas generating agent consisting of 31.5% by weight of nitroguanidine, 51.5% by weight of Sr(NO<sub>3</sub>)<sub>2</sub>, 10.0% by weight of sodium salt of carboxymethyl cellulose and 7.0% of acid clay may be used. Or a non-azide gas

generating agent consisting of 30% by weight of nitroguanidine, 54.0% by weight of Sr(NO<sub>3</sub>)<sub>2</sub>, 10.0% by weight of sodium salt of carboxymethyl cellulose and 5.0% of acid clay may be used.

The gas generating agent may further contain a selected one of various known binders, where the gas generating agent is formed into a certain shape to provide solid bodies.

The gas generating agent may be formed into a cylindrical shape with a single hole, and in this case, the surface area of each body of the gas generating agent can be increased. To enable the gas generating agent to be completely burned within a desired burning time, the smallest thickness of the cylindrical wall of the gas generating body is preferably controlled to 0.01 to 2.5 mm, more preferably, 0.01 to 1.0 mm. Where this thickness is 0.85 mm, for example, the cylindrical gas generating body with a single hole may have an outside diameter of 2.5 mm and an inside diameter of 0.8 mm. Where the thickness is 1.2 mm, the cylindrical gas generating body with a single hole may have an outside diameter of 3.2 mm and an inside diameter of 0.8 mm.

The amount of the gas generating agent contained in the gas generator is preferably in a range of 20 to 50g where the gas generator is to be used for an air bag for a driver seat, and in a range of 50 to 190g where the gas generator is to be used for an air bag for a passenger seat.

Where the gas generating agent contained in the housing is a non-azide type gas generating agent, it has a linear burning velocity of 5 to 30 or 7 to 30 mm/sec under a pressure of 70 kg/cm<sup>2</sup>. When this gas generating agent is used in gas generators for air bags installed on an automobile, the gas generating agent needs to be completely burned in 40 to 60 msec to inflate an air bag for a driver seat, and in 50 to 80 msec to inflate an air bag for a passenger seat. To control combustion of the gas generating agent, therefore, the ratio (A/At) of the total surface area A of solid bodies of the gas generating agent to the total opening area At of the gas discharge ports is controlled to be larger than 300. In the gas generator for air bags used on the side of the driver seat and passenger seat, this ratio A/At may be controlled to be larger than 300 but not larger than 1300, and preferably controlled to be in the range of 450 to 1300, more preferably, in a range of 450 to 1000. In this case, the gas generating agent can be completely burned in the above-indicated period of time.

If the ratio A/At exceeds the maximum value, the pressure in the gas generator excessively increases, and the burning velocity of the gas generating agent is excessively high. If the ratio A/At is less than the minimum value, on the other hand, the pressure in the gas generator is lowered, and the burning velocity is excessively low. In either case, the burning time of the gas generating agent is outside the desired range, and an operable gas generator cannot be provided.

When the ratio (A/At) of the total surface area A of

the gas generating agent to the total opening area. At of the gas discharge ports is controlled as described above, a difference between the maximum output pressures at 85°C and 20°C and a difference between the maximum output pressures at 20°C and -40°C in tank pressure tests using a tank whose capacity is 60 l are each 25 % or less of the maximum output pressure in the tank test at 20°C and, further, can be not higher than 40kPa. Thus, the maximum pressure in the housing upon actuation of the gas generator does not depend upon the temperature of the atmosphere, and the gas generator for an air bag according to the present invention exhibits stable operating characteristics.

In the tank pressure test, the gas generator containing the shaped bodies of gas generating agent is fixed to the inside of a tank made of SUS (stainless steel) according to Japanese Industrial Standard and having a content volume of 60 liters. After the tank is air-tightly closed, the gas generator is connected to an external ignition circuit. By using a pressure transducer installed in the tank, pressure increases or changes in the tank are measured from time 0 to 200 milliseconds where the time 0 indicates a point of time when the switch of the ignition circuit is turned on. Measurement data are processed by a computer, and finally represented as a tank pressure/time curve from which operating characteristics of the gas generator can be evaluated. In this test, a portion of the gas in the tank may be sampled out after the combustion, to be analyzed in respect of its CO and NO<sub>x</sub> components, for example. According to the present invention, the tank pressure tests are conducted at -40°C, 20°C and 85°C, to obtain the maximum output pressure (namely, maximum tank pressure) from the tank pressure/time curve at each temperature, and the difference between the maximum output pressures in the tank pressure tests at 85°C and 20°C and the difference between the maximum output pressures in the tank pressure tests at 20°C and -40°C are calculated.

When the gas generating agent burns in the housing, its burning performance depends on environments where the gas generating agent has been placed. Especially, the pressure index, which is an index "n" of the equation:  $r_b = a \cdot P^n$ , in which "r<sub>b</sub>" is a burning rate, "a" is a constant depending on the initial temperature of the gas generating agent and "P" is an internal pressure in the housing, is a factor for the burning rate of the gas generating agent. When the pressure index is large, the higher the ambient pressure of combustion (the internal pressure of the housing) is, the faster the burning rate becomes. A conventionally used azide-containing gas generating agent has a relatively low pressure index of 0.2-0.5. The effect of the ambient pressure to the burning rate is therefore small. A non-azide gas generating agent has a larger pressure index of 0.4-0.7 than the azide gas generating agent and for this reason the burning rate can remarkably change in accordance with changes of the internal pressure of the housing (the ambient pressure) during combustion.

In terms of the burning rate itself, it is known that an azide gas generating agent, such as NaN<sub>3</sub> and CuO, has a relatively high burning rate of 45-50 mm/sec at normal temperatures. On the other hand, a non-azide gas generating agent generally has a burning rate of not higher than 30 mm/sec. In other words, the azide gas generating agent is little influenced by the pressure change in combustion and can maintain a relatively high burning rate. The non-azide gas generating agent has a burning rate which changes in accordance with pressure changes in combustion. Then at a low initial combustion temperature the internal pressure of the housing becomes low and therefore a non-azide gas generating agent difficultly burns. At a high initial combustion temperature is high, to the contrary, the internal pressure of the housing becomes high and the burning rate becomes fast. When a gas generator (inflator) is produced with a non-azide gas generating agent having such a characteristic that the burning rate may greatly change with ambient temperatures, more problems appear than an inflator containing an azide-containing gas generating agent, to which the below shown structures will preferably meet.

First, in order to complete combustion within a given period in time even at a slow burning rate, it is proposed to form as thin a gas generating agent as possible and shorten a combustion distance. In this case, to avoid self-impacts caused by combustion and being destroyed and shattered by vibrations from the outside, the thickness of a gas generating agent shaped with a hole(s), specially a single-hole cylinder, may be preferably adjusted.

Then in order to complete combustion within a given time, it is proposed to improve ignitability of the gas generating agent. It is one method to enlarge or increase the surface area (A) of the gas generating agent. Then the combustion ability can become constant by decreasing changes of the pressure of the housing in combustion. For this purpose it is proposed that the area (A) of the nozzle(s) be adjusted to meet the surface area of the non-azide gas generating agent.

The non-azide gas generating agent has a burning rate which changes according to different initial temperatures in the same way as the azide-containing gas generating agent. This dependency on temperature appears almost the same way in both agents. The non-azide gas generating agent, however, has different combustion performances, depending on different ambient pressures after combustion caused by different initial temperatures. In order to decrease these differences of the combustion performance as much as possible, it is proposed that the pressure of housing be maintained to be as constant as possible by controlling A/At.

In the case of a non-azide gas generating agent, the above problems may be solved by setting the value of A/At higher than that for an azide-containing gas generating agent.

The filter means functions to remove combustion

residues produced by combustion of the gas generating agent, and to cool the combustion gas. As the filter means having these functions, a conventionally used filter for purifying the generated gas and/or a coolant for cooling the generated gas may be used, or a layered wire screen filter or the like may be used which is obtained by compressing wire screens formed of a suitable material into an annular layered structure. This layered wire screen filter may be formed, for example, by superposing some layers of plain-stitch wire mesh screens in radial directions, and compressing the wire screens in the radial and axial directions into an annular shape. The filter means thus formed has a complicated porous structure, and provides an excellent scavenging effect. Thus, the filter means provides a coolant/filter unit having both cooling and scavenging functions. More specifically, a plain-stitch wire screen made of a stainless steel is formed into a cylindrical body, and one end portion of this cylindrical body is repeatedly bent outward to form an annular layered body, which is then compressed in a mold to form the filter means. In another method, a plain-stitch wire screen or mesh sheet made of stainless steel may be formed into a cylindrical body, and the cylindrical body is pressed in a radial direction and formed into a planar body, which is then rolled cylindrically many times into a multi-layered body. This layered body is then compressed in a mold to thus form the filter means. The stainless steel used as a material for the wire screens may be selected from SUS 304, SUS 310S, SUS 316 (according to Japanese Industrial Standard). In particular, SUS 304 (18Cr-8Ni-0.06C), which is austenitic stainless steel, shows excellent corrosion resistance.

Stainless steel has been referred to in way of wire material for the coolant/filter. Without limitation to this, iron can be used advantageously from the point of cost, etc.

The filter means may have a dual-layer structure having an inner or outer layer consisting of the layered wire-screen body. The inner layer may have a function of protecting the filter means from a hot combustion gas generated by combustion of the gas generating agent. The outer layer may have functions to prevent the filter means from swelling or expanding out due to the gas pressure upon actuation of the gas generator, and closing a space formed between the filter means and an outer circumferential wall of the housing. Where the filter means is spaced apart from the inner circumferential surface of the housing, namely, where the space is formed between the outer circumferential surface of the filter means and the inner circumferential surface of the housing, this space functions as a gas passage, which permits the combustion gas to pass through the whole region of the filter means such that the gas is effectively cooled and purified during the passage.

This coolant/filter preferably has a bulk density of 3.0-5.0 g/cm<sup>3</sup>, more preferably 3.5-4.5 g/cm<sup>3</sup>. A diameter of a linear wire for a metal mesh is preferably 0.3-0.6

mm. For example, a mesh of stainless steel may have a plain-stitch structure with a wire having a diameter of 0.3-0.6 mm. In the plain-stitch structure all the stitches are dragged like loops at one direction. Wire meshes with such a structure are laid one on another at the radial direction and then pressed and molded to form a coolant/filter. The wire rod is not limited to stainless steel and a coolant/filter can also be formed by using a wire of iron to have the above described structure.

The coolant/filter of the invention can be provided with a scavenging effect of combustion residues because of a complex structure described above. This is the reason it has a certain amount of resistance (a pressure loss) against the gas flow. The resistance value, determined by the method of measuring a coolant/filter pressure loss, described later in reference to Figure 8, is preferred to range from 10 mmH<sub>2</sub>O to 2000 mmH<sub>2</sub>O, that is, from  $1 \times 10^{-3}$  kgf/cm<sup>2</sup> to  $2 \times 10^{-1}$  kgf/cm<sup>2</sup>, per an air flow of 1000 l/min in the atmosphere of 20 °C.

It is proposed that the value of pressure loss of the filter means of the present invention in a preferred embodiment should be lower than the pressure loss of the gas discharge ports of the housing and should not be any factor for determination of A/At. In other words, the filter means used appropriately in this invention does not have function to disturb a practical gas flow and control the internal combustion pressure.

The gas generator for an air bag according to the present invention may employ any type of system for sensing an impact and actuating the igniting means provided that, and the gas generator is constructed as described above. Namely, the impact sensing and igniting system may be of a mechanical ignition type in which the ignition means is actuated only by a mechanical arrangement to generate gas when an impact sensor detects an impact, or may be of an electric ignition type in which the igniting means is actuated in response to an electric signal transmitted from an impact sensor upon detection of an impact, to generate gas.

In the mechanical ignition type gas generator using mechanical igniting means, a mechanical sensor for sensing an impact only by a mechanical arrangement, for example, a sensor adapted to launch a plunger upon movement of a weight, is mounted in the housing. This housing is formed with a plurality of gas discharge ports, and incorporates a detonator that is ignited and burned when the plunger launched by the mechanical sensor enters the detonator, igniting means comprising a transfer charge that is ignited and burned by the flame of the detonator, gas generating means that is ignited and burned by the flame of the transfer charge to generate gas, and filter means for cooling and purifying the generated gas. In the electric ignition type gas generator using electrical igniting means, on the other hand, the housing having gas discharge ports incorporates igniting means comprising an igniter to be actuated in response to an electric signal transmitted from a sensor

upon detection of an impact, a transfer charge that is ignited and burned upon actuation of the igniter, gas generating means that is ignited and burned by a flame produced by the transfer charge to generate gas, and filter means for cooling and purifying the generated gas. The gas generator of mechanical ignition type or electric ignition type may employ a suitably selected structure other than the above, which is advantageous in the operating characteristics.

The gas generator of the present invention may include other elements than those indicated above, provided that the ratio (A/At) of the total surface area A of the solid bodies of the gas generating agent installed in said housing to the total opening area At of the gas discharge ports is controlled as described above. For instance, the gas generator may employ a porous cylindrical plate that surrounds the outer periphery of the filter means so as to inhibit deformation of the filter means, and short-pass preventing means (plate members, etc.) for surrounding the upper end and/or lower end of the inner periphery of the filter means so as to inhibit the generated gas from short-passing through a clearance between the filter means and an inner surface of the housing. The gas generator may also include a perforated basket having a cylindrical shape and many holes, which surrounds the inner periphery of the filter means so as to prevent direct contact between the gas generating means and the filter means.

The gas generator for an air bag, as described above, and the air bag that is inflated by the gas generated by the gas generator are accommodated in a module case, to provide an air bag system. This air bag system further includes an impact sensor for detecting an impact to actuate the gas generator. If the gas generator is of a mechanical ignition type, the impact sensor consists of a mechanical sensor, and is stored in the housing, along with the igniting means. If the gas generator is of electric ignition type, on the other hand, the impact sensor may consist of a semiconductor acceleration sensor disposed outside a console box, for example. In this semiconductor type acceleration sensor, four semiconductor strain gauges are formed on a beam of a silicon substrate that is adapted to deflect upon application of acceleration, such that these strain gauges are connected in a bridge form. The beam is deflected upon application of acceleration thereto, and strains occur on the surface of the beam. The resistance of the semiconductor strain gauges changes due to the strains, and the changes in the resistance are detected as voltage signals that are proportional to the applied acceleration. Where the electric ignition type gas generator is used, in particular, the air bag system may also include a control unit provided outside the module case. This control unit is provided with an ignition determining circuit, which receives signals from the semiconductor type acceleration sensor. At the point of time when the impact signal from the impact sensor exceeds a given value, the control unit starts computing, and generates

an actuation signal to the gas generator when the result of computing exceeds a given value.

In this air bag system, the gas generator is actuated in association with sensing of an impact by the impact sensor, so as to discharge the combustion gas through its gas discharge ports. The combustion gas is expelled into the air bag, so as to inflate the air bag while breaking the module cover, so that the inflated air bag forms a cushion between a hard structure in the vehicle and a passenger.

#### [Brief Description of the Drawings]

Fig. 1 is a cross sectional view showing a gas generator according to one embodiment of the present invention;

Fig. 2 is a cross sectional view showing a gas generator according to another embodiment of the present invention;

Fig. 3 is a cross sectional view of one half of a gas generator according to yet another embodiment of the present invention;

Fig. 4 is a cross sectional view of one half of a gas generator according to a still another embodiment of the present invention;

Fig. 5 is a cross sectional view showing a gas generator of the present invention suitable for an air bag system for a passenger seat;

Fig. 6 is a view showing the construction of an air bag system of the present invention; and

Fig. 7 is a graph showing results of tank pressure tests.

Figure 8 is a schematic view of a measuring device of pressure loss of the coolant/filter.

Figure 9 is a schematic view of a measuring device of an air flow resistance (pressure loss) of the gas discharge ports.

#### [Description of Reference Numerals]

1	Diffuser shell
2	Closure shell
3	Housing
4	Igniter
6	Gas generating agent
7	Coolant/filter
11	Gas discharge port

#### [Description of the Preferred Embodiments]

Referring to the drawings, preferred embodiments of the present invention will be hereinafter described.

Fig. 1 and Fig. 2 show gas generators for air bags used on the side of a driver seat. Fig. 1 is a cross sectional view showing a gas generator for an air bag according to the present invention. The present gas generator includes a housing 3 having a diffuser shell 1 and a closure shell 2, igniting means, i.e., an igniter 4

and a transfer charge 5, provided in a storage space in this housing 3, a gas generating agent 6 that is ignited by the igniting means to generate combustion gas, and filter means, i.e., a coolant/filter 7, which defines a combustion chamber 28 for storing the gas generating agent 6.

The diffuser shell 1 is formed by pressing a stainless steel sheet, and has a circular portion 12, a circumferential wall portion 10 formed at the outer periphery of the circular portion 12, and a flange portion 19 formed at the distal end of the circumferential wall portion 10 to extend radially outward from this portion 10. In the present embodiment, sixteen 3mm-diameter gas discharge ports 11 (the total opening area of the gas discharger ports  $A_t = 113 \text{ mm}^2$ ) are formed through the circumferential wall portion 10, such that these discharge ports 11 are equally spaced apart from each other in the circumferential direction. This diffuser shell 1 includes an inclined portion 49 which provides an outwardly protruding circular portion 13 formed in a middle part of the circular portion 12. This inclined portion 49 serves to increase the rigidity of the housing, in particular, of the circular portion 12 of the diffuser shell that forms a ceiling portion of the housing, and also serves to increase the volume of the storage space of the housing. A transfer charge container 53 for storing the transfer charge 5 is sandwiched by and between the protruding circular portion 13 and the igniter 4.

The closure shell 2 is formed by pressing a stainless steel sheet, and has a circular portion 30, central aperture 15 formed through a central portion of the circular portion 30, a circumferential wall portion 47 formed at the outer periphery of the circular portion 30, and a flange portion 20 formed at the distal end of the circumferential wall portion 47 to extend radially outwards from this portion 47. The central aperture 15 is defined by an axial bent portion 14 of the closure shell 2 which extends from the circular portion 30 in the axial direction. This bent portion 14 serves to increase the rigidity of the peripheral portion of the central aperture 15, and provides a relatively large surface to be joined to a central cylindrical member 16. The central cylindrical member 16 is fitted in this central aperture 15, such that one of opposite end faces 17 of the central cylindrical member 16 is flush with an end face 18 of the bent portion 14.

The diffuser shell 1 and closure shell 2 are joined together by superposing the flange portion 19 of the diffuser shell 1 and the flange portion 20 of the closure shell 2 at an axially middle position of the housing 3 and performing a laser welding 21 to form the housing 3. These flange portions 19, 20 serve to increase the rigidity of the housing 3, in particular, its outer circumferential wall 8, thereby preventing deformation of the housing due to the pressure of the generated gas.

The central cylindrical member 16 consists of a stainless steel tube which is open at both ends, and fixed at one end to the protruding circular portion 13 of

the diffuser shell 1 by electron beam welding 22. An ignition means storage chamber 23 is formed inside this central cylindrical member 16, and the igniter 4 and the transfer charge container 53 are disposed within the igniting means storage chamber 23. The igniter 4 is actuated in response to a signal from a sensor (not shown), and the transfer charge 5 filling the transfer charge container 53 is ignited or fired by the igniter 4. The central cylindrical member 16 has a holding member 24 for holding the igniter 4, and this holding member 24 consists of an inward flange portion 25 for limiting axial movement of the igniter 4, a cylindrical portion 26 in which the igniter 4 is fitted and which is fixed to the inner circumferential surface of the central cylindrical member 16, and a crimped portion 27 formed by crimping, which cooperates with the inward flange portion 25 to fix the igniter 4 in place in the axial direction. The central cylindrical member 16 also has through-holes 54 formed in one end portion thereof remote from the holding member 24. In the present embodiment, six through holes 54 having a diameter of 2.5 mm are formed at regular intervals in the circumferential direction.

The central cylindrical member 16 is formed by rolling a stainless steel sheet into a tube. In the case of an electric ignition type gas generator, the central cylindrical member 16 is formed by rolling a stainless steel sheet having a thickness of 1.2 to 3.0 mm into a tubular shape, and welding its joint to form a tube having an outside diameter of 17 to 22 mm. In the case of a mechanical ignition type gas generator, the central cylindrical member 16 is formed by rolling a stainless steel sheet having a thickness of 1.5 to 7.0 mm into a tubular shape, and welding its joint to form a tube having an outside diameter of 19 to 30 mm. Such a welded tube may be formed by a UO press method (in which a sheet is formed into U shape, and then into O shape, followed by welding of its joint), or formed as an electric resistance welded tube (obtained by forming a sheet into a circular shape, and welding its joint under pressure with a large current flowing through it while generating resistance heat).

The coolant/filter 7 is disposed so as to surround the gas generating agent 6, and defines an annular chamber, namely, a combustion chamber 28, around the central cylindrical member 16. This coolant/filter 7 is formed by superposing some layers of plain-stitch wire screens made of stainless steel in the radial direction, and compressing the wire screens in the radial and axial directions. In this coolant/filter 7, each layer has a loop-like mesh that is squashed or pressed out of shape, and such layers are laminated on each other in the radial direction. Thus, the coolant/filter 7 has a complicated porous structure, and provides an excellent scavenging effect. An outer layer 29 consisting of a layered wire net structure is formed outside the coolant/filter 7. This outer layer 29 serves as means for preventing the coolant/filter 7 from swelling or expanding out into a space 9 due to the gas pressure upon actuation of the gas gen-

erator, so that the space 9 is not closed by the coolant/filter 7. This outer layer 29 also has a cooling function. This outer layer 29 includes, for example, a porous cylinder and a belt-like layer, called as a swell-suppressor. The coolant/filter 7 defines the combustion chamber 28, and serves to cool the combustion gas generated in the combustion chamber 28 while scavenging or entrapping combustion residues.

The closure shell 2 includes an inclined portion 31 formed in the circumferential direction so as to surround its circular portion 30. This inclined portion 31 functions to inhibit radial movement of the coolant/filter 7, and also functions to form the space between the outer circumferential wall 8 of the housing and the coolant/filter 7.

A large number of solid bodies of gas generating agent 6 are provided in the combustion chamber 28. Each body of the gas generating agent 6 has a hollow, cylindrical shape, which is advantageous in that combustion takes place at its outer surface and inner surface at the same time, and the overall surface area of the gas generating agent 6 does not significantly change as the combustion progresses. In the present embodiment, the gas generating agent contains 25 to 60% by weight of nitroguanidine, 40 to 65% by weight of strontium nitrate, and 1 to 20% by weight of acid clay, and is formed into a hollow cylindrical shape having an outside diameter of 2.4 mm, inside diameter of 0.8 mm, and a length of 2 mm. The combustion chamber 28 of the housing is filled with 37g of the gas generating agent (having a linear burning velocity of 11 mm/sec at the pressure of 70 kgf/cm<sup>2</sup>, the total surface area of the gas generating agent bodies:  $A = 56804 \text{ mm}^2$ ).

Plate members 32, 33 are provided at the upper end portion and lower end portion of the coolant/filter 7, respectively. The plate member 32 consists of a circular portion 36 closing an opening 40 at the upper end portion of the coolant/filter 7, and a circumferential portion 34 formed integrally with the circular portion 36 and abutting on an inner circumferential surface 41 of the coolant/filter 7. The circular portion 36 has a central aperture 35 fitting on the outer periphery of the central cylindrical member 16. The circumferential wall portion 34 is opposed to the through-holes 54 through which a flame is ejected from the igniting means, and covers the inner circumferential surface 41 of the coolant/filter 7 facing the through-holes 54. This circumferential wall portion 34 prevents the coolant/filter 7 from being damaged by the flame ejected toward the coolant/filter 7, and also functions to change the direction of the ejected flame so that the flame is sufficiently circulated through the gas generating agent 6. The plate member 32 is fixed to the central cylindrical member 16 which limits radial movement of the plate member 32, and thus serves as means for positioning the coolant/filter 7 during assembly of the gas generator. The plate member 32 also functions as short-pass preventing means for preventing the combustion gas from short-passing

through a clearance between an inner surface 37 of the housing and an end face 38 of the coolant/filter 7, which clearance may appear due to the pressure of the combustion gas upon actuation of the gas generator.

The plate member 33 consists of a circular portion 50 for closing an opening 42 at the lower end portion of the coolant/filter 7, and a circumferential wall portion 51 formed integrally with the circular portion 50 and abutting on the inner circumferential surface 41 of the coolant/filter 7. The circular portion 50 has a central aperture 39 fitted on the outer periphery of the central cylindrical member 16, and is in contact with the solid bodies of gas generating agent 6 to prevent movement of these gas generating bodies. The plate member 33 is gripped or held by resilient force between the central cylindrical member 16 and the coolant/filter 7, and prevents the combustion gas from passing along an end face 43 of the coolant/filter 7 opposite to the above-indicated end face 38. The plate member 33 also functions as a welding protective plate during welding.

A space 9 is formed between the outer circumferential wall 8 of the housing and the outer layer 29 of the coolant/filter 7. With the space 9 thus provided, an annular gas passage is formed around the coolant/filter 7 as viewed in a radial cross section. The area  $S_1$  of the gas passage as measured in the radial cross section is made larger than the sum  $A_1$  of opening areas  $S$  of the gas discharge ports 11 of the diffuser shell. In the presence of the gas passage around the coolant/filter 7, the combustion gas passes through the whole region of the coolant/filter 7, to be directed toward the gas passage, thereby achieving efficient use of the coolant/filter 7 and effective cooling and purification of the combustion gas. The combustion gas, thus cooled and purified by the coolant/filter 7 reaches the gas discharge ports 11 of the diffuser shell 1, through the gas passage as described above.

An aluminum tape 52 is attached to the diffuser shell 1 to close the gas discharge ports 11, so as to inhibit entry of moisture from the exterior space into the housing 3.

In the gas generator of the present embodiment, the ratio  $(A/A_1)$  of  $A$  to  $A_1$  is 502 where  $A$  ( $56804 \text{ mm}^2$ ) is the sum of surface areas or total surface area of the solid bodies of gas generating agent 6, and  $A_1$  ( $113 \text{ mm}^2$ ) is the total opening area of the gas discharge ports 11 of the diffuser shell 1. This ratio  $A/A_1$  is generally controlled to be in the range of 450 to 1000. With the ratio  $A/A_1$  thus controlled, the burning velocity of the gas generating agent is controlled to be suited for air bags for driver seats, and the gas generating agent mounted in the present gas generator can be completely burned within a desired period of time. Also, the present gas generator is less likely to be influenced by changes in the temperature of the atmosphere, thus assuring stable operating characteristics.

In assembling the gas generator of the present embodiment, the diffuser shell 1 to which the central

cylindrical member 16 is joined is placed on its bottom provided by the protruding circular portion 13, and the plate member 32 is passed along the central cylindrical member 16. The coolant/filter 7 is then fitted on the outside of the circumferential wall portion of the plate member 32, so that the coolant/filter 7 is positioned by the plate member 32. The space inside the coolant/filter 7 is filled with the solid bodies of gas generating agent 6, and then covered with the plate member 33. Thereafter, the closure shell 2 is mounted on the plate member 33 by inserting the central cylindrical member 16 through the central aperture 15 of the closure shell 2, and the flange portion 20 of the closure shell 2 is superposed on the flange portion 19 of the diffuser shell 1. In this state, the diffuser shell 1 is joined to the closure shell 2 by laser welding 21, and the closure shell 2 is joined to the central cylindrical member 16 by laser welding 44. In the final step, the transfer charge container 53 and igniter 4 are inserted into the central cylindrical member 16, and a crimped portion 27 of an igniter holding member is crimped so as to fix the container 53 and igniter 4 in position.

In the present gas generator constructed as described above, when an impact is detected by a sensor (not shown), a signal is transmitted from the sensor to the igniter 4, which is then actuated to ignite or fire the transfer charge 5 in the transfer charge container 53, thereby producing a high-temperature flame. This flame is ejected through the through-holes 54; to ignite the gas generating agent 6 around the through-holes 54, and then directed downward to ignite the gas generating agent 6 located in the lower portion of the combustion chamber. As a result, the gas generating agent 6 burns to produce high-temperature, high-pressure gas, and the combustion gas thus produced passes through the whole region of the coolant/filter 7, where the gas is effectively cooled and the combustion residues are scavenged or entrapped during the passage. The combustion gas thus cooled and purified passes through the gas passage (space 9), and ruptures the aluminum tape 52, to be ejected or expelled through the gas discharge ports 11 and flows into an air bag (not shown). The air bag then inflates to form a cushion between a passenger and a hard structure, thereby protecting the passenger from the impact.

Fig. 2 is a cross sectional view showing a gas generator for an air bag according to another embodiment of the present invention. The present gas generator includes a housing 63 consisting of a diffuser shell 61 and a closure shell 62, an igniter 64 disposed in a storage space within the housing 63, a gas generating agent 66 that is to be ignited by the igniter 64 to produce combustion gas, and a coolant/filter 67 that defines a combustion chamber 84 for storing the gas generating agent 66.

The diffuser shell 61 is formed by pressing a stainless steel sheet, and has a circular portion 78, a circumferential wall portion 76 formed at the outer periphery of

the circular portion 78, and a flange portion 86 formed at the distal end of the circumferential wall portion 76 to extend radially outward from this portion 76. A plurality of gas discharge ports 77 are formed through the circumferential wall portion 76 at regular intervals in the circumferential direction. The circular portion 78 of the diffuser shell 61 has a plurality of rib-like reinforcing portions 79 formed in radial directions. These rib-like reinforcing portions 79 serve to increase the rigidity of the housing, in particular, of the circular portion 78 of the diffuser shell that provides a ceiling portion of the housing, thereby inhibiting the housing from being deformed due to the gas pressure.

The closure shell 62 is formed by pressing a stainless steel sheet, and has a circular portion 71, a circumferential wall portion 72 formed at the outer periphery of the circular portion 71, and a flange portion 87 formed at the distal end of the circumferential wall portion 72 to extend outward from this portion 72. The circular portion 71 has a recessed portion 73 formed with a stepped portion 48 in its central portion, and a central aperture 74 formed through a central part of the recessed portion 73. The central aperture 74 is defined by an axial bent portion 75 formed at the inner periphery of the closure shell 62. The bent portion 75 has an inner circumferential surface 81 in which a barrel portion 80 of the igniter is fitted, and an end face 83 that engages with a mounting portion 82 of the igniter. The inner circumferential surface 81 of the axial bent portion 75 provides a relatively large area for sealing the interior of the housing. To ensure the air-tightness of the housing, a sealing material may fill an interface between the barrel portion 80 of the igniter and the inner circumferential surface 81 of the bent portion 75, or the mounting portion 82 of the igniter may be welded to the end face 83 of the bent portion 75. The end face 83 engaging with the mounting portion 82 of the igniter serves to prevent the igniter 64 from being pulled out of the housing due to the gas pressure in the combustion chamber 84. The stepped portion 48 of the closure shell 62 increases the rigidity of the housing, in particular, of the circular portion 71 that provides a bottom portion of the housing. With the recessed portion 73 formed as described above, a connector bottom face 85 of the igniter is positioned inwardly of the outer surface of the circular portion 71. The bent portion 75 serves to increase the rigidity of the peripheral portion of the central aperture 74.

The housing 63 is formed by superposing the flange portion 86 of the diffuser shell 61 and the flange portion 87 of the closure shell 62 on each other at an axially middle position of the housing 63, and subjecting it to a laser beam welding 88, thus joining the diffuser shell 61 and closure shell 62. These flange portions 86, 87 serve to increase the rigidity of the outer circumferential wall 68 of the housing, thereby preventing deformation of the housing due to the pressure of the generated gas.

The igniter 64 includes a generally used electric

igniter adapted to be actuated in response to a signal from a sensor (not shown). The electric igniter is more preferable than a mechanical igniter, since it has a simplified structure with no mechanical arrangement, and has reduced size and weight. In the present embodiment, the igniter 64 (its output is 300 to 1500 psi in a closed pressure vessel of 10cc) is not accompanied by the transfer charge container 53 as shown in Fig. 1 or the like, because the gas generating agent 66 has good ignition and combustion characteristics. The gas generating agent 66 has a hollow, cylindrical shape, which is advantageous in that combustion takes place at its outer surface and inner surface, and the overall surface area of the gas generating agent 66 does not significantly change as the combustion progresses.

The coolant/filter 67 is disposed concentrically with the central aperture 74, and cooperates with the housing 63 to define the combustion chamber 84. This coolant/filter 67 is formed by superposing some layers of plain-stitch wire screens made of stainless steel in the radial direction, and compressing the wire screens in the radial direction and axial direction. The coolant/filter 67 defining the combustion chamber 84 serves to cool combustion gas generated in the combustion chamber 84, and scavenge or entrap combustion residues. An outer layer 89 consisting of a layered wire net structure is formed outside the coolant/filter 67, and serves to reinforce the coolant/filter and cool the combustion gas.

The method of measuring a pressure loss of the coolant/filter will be described below.

In Figure 8 is shown a schematic view of a measuring device of pressure loss of the coolant/filter. This is an embodiment of a method for determining a value of pressure loss of the coolant/filter 300 made of stainless wire rolled up into a cylindrical shape. A certain amount of air is blown from the inside of a tested coolant 300. As seen in Figure, the coolant/filter is equipped at one end with a supporting plate 303 having a air-feeding tube and at the other end with a supporting plate 303, thereby to avoid air from leaking, with a manometer 304, installed. Therefore, air blown through the tube 302, attached to a supporting plate 303 joined to one end of the cylindrical coolant/filter 300 has to flow outwardly through the cylindrical side of the coolant/filter 300. In this case, the tube 302 where a certain amount of air passes should have a sufficiency large cross-sectional area and a smooth internal wall to obtain a precise result of pressure loss. The numeral reference to 305 is a flow meter to send a constant amount of air to the coolant/filter. Sealing means such as packing is applied on the contacting surfaces between the supporting plates and the side ends of the coolant/filter so that the coolant/filter may be firmly inserted between the supporting plates and air may not leak out of between the contacting surfaces. When a given amount of air is fed under these conditions, part of the air blown into the coolant 300 goes out from the side of cylindrical coolant/filter 300, accompanied by a decreased pressure

observed. This is a determination of air flow resistance of the coolant/filter. In other words, a value which the manometer shows is a pressure loss of the coolant/filter 300.

There are shown results of air flow resistance of a coolant/filter having an outer diameter of 60 mm, an inner diameter of 47 mm and a height of 29.5 mm, made of stainless steel wire having a diameter of 0.5 mm, an amount of air blown being 1000 l/min. When the shape and the wire's diameter are constant, an air flow resistance of the coolant/filter depends on its apparent bulk density (weight/volume) of the coolant/filter. For example, an apparent bulk density is 3 g/cm<sup>3</sup> gives an air flow resistance of 70 mmH<sub>2</sub>O (0.007 kgf/cm<sup>2</sup>). 4 g/cm<sup>3</sup> gives 300 mmH<sub>2</sub>O (0.030 kgf/cm<sup>2</sup>). 5 g/cm<sup>3</sup> gives 800 mmH<sub>2</sub>O (0.080 kgf/cm<sup>2</sup>). It is noted that the air flow resistance of the coolant/filter is well correlated with the density.

Then it is possible to measure an air flow resistance of the gas discharge ports or gas flow-throttling means. A method of measuring an air flow resistance of the gas discharge ports is shown in Figure 9. This measuring method is, in principle, the same as that for measuring a pressure loss of the coolant/filter as shown in Figure 8. Namely, in Figure 9, a manometer 304 is attached to the diffuser shell 307 having gas discharge ports, which is equivalent to the upper supporting plate with a manometer 304 placed over the upper end of the coolant/filter in Figure 8. For accurate measurement of an air flow resistance of the gas discharge ports, it is necessary to prevent the air flowed into the diffuser shell 307 through the tube 302 from leaking out of any means except the gas discharge ports. Therefore, the diffuser shell 307 is pressed on a supporting plate 303 through an O-ring 306 inbetween. In Figure 9, the diffuser shell 307 is pressed to be fixed to the supporting plate 303 with screws using an air bag module attachment holes formed on the flange portion of the diffuser shell. The O-ring 306 prevents air from leaking from between the flange of the diffuser shell 307 and the supporting plate 303. And for accurate measurement of the pressure loss, the tube 302 has a sufficientsy large cross-sectional area against the amount of the air flow described in Figure 8, and a smooth internal wall. Under these considitions, when a given amount of air is flown into a tube 302, a portion of air having entered in the diffuser shell goes out from the gas discharge ports 301 and a decrease pressure can be observed. As a result, an air flow resistance of the gas discharge ports is taken from a value (pressure loss) which the manometer shows. If the air flow resistance of the gas discharge ports obtained by the above shown method is sufficiently larger than that of the coolant/filter, the relation; A/At, can be accurately defined and determined. The air flow resistance of the gas discharge ports is 12000 mmH<sub>2</sub>O (1.2 kgf/cm<sup>2</sup>) for the total open area of the gas discharge ports of 50 mm<sup>2</sup>. It is 2500 mmH<sub>2</sub>O (0.25 kgf/cm<sup>2</sup>) for 100 mm<sup>2</sup> and 1000 mmH<sub>2</sub>O (0.1 kgf/cm<sup>2</sup>)

for 200 mm<sup>2</sup>. This way the air flow resistance of the gas discharge ports is well correlated with the total area of the gas discharge ports.

In an embodiment of the invention it was found that an air flow resistance of gas-discharging ports having a total area of 91 mm<sup>2</sup> was 4000 mmH<sub>2</sub>O (0.4 kgf/cm<sup>2</sup>) and an air flow resistance of the coolant/filter having a density of 4 g/cm<sup>3</sup> was 300 mmH<sub>2</sub>O (0.030 kgf/cm<sup>2</sup>).

The closure shell 62 formed by press working includes an inclined portion 90 formed in the circumferential direction to surround its circular portion 71. This inclined portion 90 serves to position the coolant/filter 67 and inhibit radial movement of the coolant/filter 67, and also serves as means for forming a space 69 between the outer circumferential wall 68 of the housing 63 and the outer layer 89 of the coolant/filter.

A large number of solid bodies of gas generating agent 66 each having a hollow cylindrical shape are provided in the combustion chamber 84. The bodies of gas generating agent 66 are directly loaded in the space inside the combustion chamber 84, to be disposed adjacent to the igniter 64, and their movements are limited by a circular portion 92 of a plate member 91 that closes an opening 45 defined by one end portion of the coolant/filter 67. The plate member 91 has the circular portion 92, and a circumferential wall portion 93 formed integrally with the circular portion 92, which abuts on an inner circumferential surface of the above-indicated one end portion of the coolant/filter 67 to cover the inner circumferential surface. The plate member 91 prevents the combustion gas from short-passing through a clearance between one end face 94 of the coolant/filter and the circular portion 78 of the diffuser shell. The other end face 95 of the coolant/filter at which the plate member 91 is not provided is fixed to the inner face 46 of the housing by welding, thereby to prevent the combustion gas from passing along the other end face 95. With the end face 95 of the coolant/filter welded to the inner face 46 of the housing, a packing formed of silicon rubber or the like and having flame resistance and resiliency need not be provided between the end face 95 of the coolant/filter and the inner face 46 of the housing.

The space 69 is formed between the outer circumferential wall 68 of the housing and the outer layer 89 of the coolant/filter, so as to form an annular gas passage around the coolant/filter 67, as viewed in a radial cross section. As in the gas generator shown in Fig. 1, the area of the gas passage as measured in the radial cross section is made larger than the total opening area of the gas discharge ports 77 of the diffuser shell. By the presence of the gas passage around the coolant/filter, the combustion gas passes through the whole region of the coolant/filter 67, to be directed toward the gas passage, thereby achieving efficient use of the coolant/filter 67 and effective cooling and purification of the combustion gas. The combustion gas thus cooled and purified by the coolant/filter 67 reaches the gas discharge ports 77 of the diffuser shell 61, through the gas passage as

described above. An aluminum tape 96 is attached to the inside of the housing so as to close the gas discharge ports 77 of the diffuser shell.

In the gas generator of the present embodiment, the ratio (A/At) of A to At is controlled to be in the range of 450 to 1000, as in the gas generator of Fig. 1, where A is the total surface area of the solid bodies of gas generating agent 66; and At is the total opening area of the gas discharge ports 77 of the diffuser shell 61. With the ratio A/At thus controlled, the burning velocity of the gas generating agent is controlled to be suited for an air bag installed on the side of a driver seat, and the gas generating agent provided in the present gas generator can be completely burned within a desired period of time. Also, the present gas generator is less likely to be influenced by changes in the temperature of the atmosphere, thus assuring stable operating characteristics.

In assembling the gas generator of the present embodiment, the closure shell 62 is placed such that its circular portion 71 is placed at the bottom, and the igniter 64 is disposed in the central aperture 74. Then the coolant/filter 67 is disposed on the closure shell 62, and the inner space of the coolant/filter 67 is filled with the gas generating agent 66, and then covered with the plate member 91. Finally, the flange portion 86 of the diffuser shell and the flange portion 87 of the closure shell are superposed on each other, and subjected to laser welding 88, so that the diffuser shell 61 and closure shell 62 are joined together.

In the present gas generator constructed as described above, when an impact is detected by a sensor (not shown), a signal is transmitted from the sensor to the igniter 64, which is then actuated to ignite the gas generating agent 66 in the combustion chamber 84. As a result, the gas generating agent 66 burns to produce high-temperature, high-pressure gas; and the combustion gas thus produced passes through the whole region of the coolant/filter 67, where the gas is effectively cooled and the combustion residues are scavenged or entrapped during the passage. The combustion gas thus cooled and purified passes through the gas passage provided by the space 69, and ruptures the aluminum tape 96, to be ejected through the gas discharge ports 77 and flow into an air bag (not shown). The air bag then inflates to form a cushion between a passenger and a hard structure, thereby to protect the passenger from the impact.

Fig. 3 shows an example of a gas generator, which is similar to that of Fig. 1, wherein a diffuser shell 1' and a closure shell 2' are formed by casting, using an aluminum alloy. The diffuser shell 1' has a circular portion 12', a central cylindrical portion 16' formed integrally with the circular portion 12', a circumferential wall portion 10' formed at the outer periphery of the circular portion 12', and a flange portion 19' formed at the distal end of the circumferential wall portion 10' to extend radially outward from this portion 10'. The closure shell 2' has a circular portion 30', a central aperture 15' formed through

a middle part of the circular portion 30', a circumferential wall portion 47' formed at the outer periphery of the circular portion 30', and a flange portion 20' formed at the distal end of the circumferential wall portion 47' to extend radially outward from this portion 47'. The central cylindrical portion 16' of the diffuser shell is fitted in the central aperture 15' of the closure shell. The flange portion 19' of the diffuser shell and the flange portion 20' of the closure shell are superposed on each other, and subjected to laser welding 21', so that the diffuser shell 1' and closure shell 2' are joined together to form a housing 3'. In Fig. 3, the same reference numerals as used in Fig. 1 are used to identify the same elements and detailed description thereof are omitted.

Fig. 4 shows an example of a gas generator, which is similar to that of Fig. 2, having a diffuser shell 61' and a closure shell 62' are formed by casting, using an aluminum alloy. The diffuser shell 61' has a circular portion 78', a circumferential wall portion 76' formed at the outer periphery of the circular portion 78', and a flange portion 86' formed at the distal end of the circumferential wall portion 76' to extend radially outward from this portion 76'. The closure shell 62' has a circular portion 71', a circumferential wall portion 72' formed at the outer periphery of the circular portion 71', and a flange portion 87' formed at the distal end of the circumferential wall portion 72' to extend radially outward from this portion 72'. A central aperture 74' is formed through a middle part of the circular portion 71'. The barrel portion 80' of the igniter 64 is fitted in the central aperture 74' of the closure shell 62', and the mounting portion 82 of the igniter 64 engages with an inner surface 129 of the circular portion 71' of the closure shell 62'. The flange portion 86' of the diffuser shell and the flange portion 87' of the closure shell are superposed on each other, and subjected to laser welding 88, so that the diffuser shell 61' and closure shell 62' are joined together to form a housing 63'. In Fig. 4, the same reference numerals as used in Fig. 2 are used to identify the same elements and detailed description thereof are omitted.

Fig. 5 shows a gas generator for an air bag to be used on the side of a passenger seat. This gas generator has a housing 104 having a cylindrical portion 101 and side wall portions 102, 103 provided at the opposite ends of the cylindrical portion 101. A plurality of gas discharge ports 100 are formed through the cylindrical portion 101, such that they are arranged in its circumferential and axial directions. A transfer tube 105 is provided in a central portion of the housing 104, and a large number of discs of gas generating agent 106 are arranged in parallel with each other to fit on the outer surface of the transfer tube 105. Further, a coolant/filter 107 is provided to surround the gas generating agents 106. Igniting means comprising a transfer charge 108 and an igniter 109 is provided at one of the side wall portions 102, and is accommodated in the transfer tube 105. A screw bolt 110 for fixing the inflator to a module is fixed to the other side wall portion 103. The transfer

tube 105 is provided with a large number of openings 111 through which a flame generated by the transfer charge 108 is ejected, such that the openings 111 are formed through the cylindrical wall of the transfer tube 105 at regular intervals. An aluminum tape 124 is secured to the inner surface of the housing 104 to cover at least a region of the housing 104 where the gas discharge ports 100 are formed. This aluminum tape 124 air-tightly closes the discharge ports 100, so as to prevent entry of moisture from the exterior space into the housing through the discharge ports 100.

Plate members 112, 113 are respectively provided at right-hand and left-hand end portions of the coolant/filter 107 as viewed in Fig. 5. The plate member 112 consists of a circular portion 115 for closing an opening 144 at the right-hand end portion of the coolant/filter 107, and a circumferential wall portion 117 formed integrally with the circular portion 115 and abutting on an inner circumferential surface 116 of the coolant/filter 107. The circular portion 115 has a central aperture 118 in which the transfer tube 105 is fitted. The plate member 113 has a circular portion 121, a circumferential wall portion 122, and a central aperture 123, which are similar to those of the plate member 112. These plate members 112, 113 are fixed to the transfer tube 105 such that radial movements of these members 112, 113 are limited or restricted by the tube 105, and thus serve to position the coolant/filter 107 during assembly of the gas generator. The plate members 112, 113 also serve as means for inhibiting movement of the coolant/filter 107 due to vibrations of the vehicle and as short-pass preventing means for preventing combustion gas from short-passing through a clearance between the inner surface 119 of the housing and an end face 120 of the coolant/filter upon actuation of the gas generator.

A space 125 is formed between the cylindrical portion 101 of the housing and the coolant/filter 107. With the space 125 thus provided, an annular gas passage as viewed in a radial cross section is formed around the coolant/filter 107. The area  $S_t$  of the gas passage as measured in the radial cross section is made larger than the sum  $At$  of opening areas  $S$  of the gas discharge ports 100 of the cylindrical portion. By the presence of the gas passage, the combustion gas passes through the whole region of the coolant/filter, to be directed toward the gas passage, thereby achieving efficient use of the coolant/filter and effective cooling and purification of the combustion gas. The combustion gas thus cooled and purified by the coolant/filter 107 reaches the gas discharge ports 100 of the cylindrical portion of the housing, through the gas passage as described above.

In the present gas generator, the ratio  $A/At$  is controlled to be in the range of 450 to 1000 where  $A$  is the total surface area of the gas generating discs 106, and  $At$  is the total opening area of the gas discharge ports 100 of the cylindrical portion. In this embodiment, where 32 gas discharge ports having an inside diameter of 3 mm are formed, the sum  $At$  of their opening areas is 226

mm<sup>2</sup>, and where the housing is filled with 400g of gas generating agent as shown in Fig. 1, the sum A of the surface areas thereof is 153524 mm<sup>2</sup>, resulting in a ratio A/At of 679. With the ratio A/At thus controlled, the burning velocity of the gas generating agent is controlled to be suited for an air bag to be used on the side of a passenger seat, and the gas generating agent provided in the present gas generator can be completely burned within a desired period of time. Also, the present gas generator is less likely to be influenced by the temperature of the outside atmosphere, thus assuring stable operating characteristics.

When an impact is detected by a sensor, a signal is transmitted from the sensor to the igniter 109, which is then actuated to ignite or fire the transfer charge 108 to generate a high-temperature flame. The flame is ejected through the openings 111 of the transfer tube 105, and ignites the gas generating discs 106 provided around the openings 111. As a result, the gas generating agent 106 burns to produce high-temperature, high-pressure combustion gas. The combustion gas thus produced passes through the whole region of the coolant/filter 107, where the gas is effectively cooled and the combustion residues are scavenged or entrapped during the passage. The combustion gas thus cooled and purified passes through the gas passage (space 125), and ruptures the aluminum tape 124, to be ejected through the gas discharge ports 100 and flow into an air bag (not shown). The air bag then inflates to form a cushion between a passenger and a hard structure, thereby to protect the passenger from the impact.

Fig. 6 shows an example of an air bag system having the gas generator of the present invention. This air bag system includes a gas generator 200; an impact sensor 201; a control unit 202; a module case 203; and an air bag 204.

The gas generator explained above with reference to Fig. 1 is used as the gas generator 200.

The impact sensor 201 may consist of a semiconductor type acceleration sensor, for example. In this semiconductor type acceleration sensor, four semiconductor strain gauges are formed on a beam of a silicon substrate that is adapted to deflect upon application of acceleration, such that these strain gauges are connected in a bridge form. The beam is deflected upon application of acceleration thereto, and strains occur on the surface of the beam. The resistance of the semiconductor strain gauges changes due to the strains, and the changes in the resistance are detected as voltage signals that are proportional to the applied acceleration.

The control unit 202 includes an ignition determining circuit, which receives signals from the semiconductor type acceleration sensor. At the point of time when the impact signal from the impact sensor exceeds a predetermined value, the control unit 202 starts computing, and generates an actuation signal to the igniter 4 of the gas generator 200 when the result of computing exceeds a predetermined value.

The module case 203 is formed of polyurethane, for example, and includes a module cover 205. The air bag 204 and the gas generator 200 are accommodated in the module case 203, to thereby provide a pad module which is attached to a steering wheel 207 of an automobile.

The air bag 204 is formed of nylon (nylon 66, for example), polyester or other material, and fixed to the flange portion of the gas generator as it is folded, with its opening 206 surrounding the gas discharge ports of the gas generator.

When the semiconductor type acceleration sensor 201 detects an impact upon crash of the automobile, an output signal of the sensor 201 is transmitted to the control unit 202, and the control unit 202 starts computing at the point of time when the impact signal from the sensor exceeds the above predetermined value. The control unit 202 then generates an actuation signal to the igniter 4 of the gas generator 200 when the result of computing exceeds the above predetermined value. As a result, the igniter 4 is actuated to ignite the gas generating agent, so that the gas generating agent burns to produce combustion gas. The gas thus generated is expelled into the air bag 204, so as to inflate the air bag 204 while breaking the module cover 205, so that the inflated air bag 204 forms a cushion between the steering wheel 207 and the passenger so as to absorb the impact.

In the gas generator of the present invention constructed as described above, the gas generating agent provided in the gas generator can be completely burned within a desired period of time, and the maximum pressure in the housing upon actuation of the gas generator is unlikely to be influenced by changes in the temperature of the atmosphere, thereby assuring stable operating characteristics of the gas generator.

[0074]

[Example]

"Tank Pressure Test"

Tank pressure tests using a tank whose capacity is 60 l were conducted at 85°C, 20°C and -40°C, using a gas generator for the driver seat in which the total surface area A of solid bodies of gas generating agent and the total opening area At of gas discharge ports are controlled to respective values as indicated below. The results of the tests are shown in Fig. 7.

-Gas generator-

The total opening area At of gas discharge ports (16 gas discharge ports each having an inside diameter of 3.0 mm) was 113 mm<sup>2</sup>.

The bulk density of the coolant/filter was 4.03 g/mm<sup>3</sup>.

The pressure loss of the coolant/filter against 1000

l/min of an air flow at the tempreture of 20 °C was 300 mmH<sub>2</sub>O (0.03 kgf/cm<sup>2</sup>)

-Gas generating agent-

The composition (weight ratio): nitroguanidine/Sr(NO<sub>3</sub>)<sub>2</sub>/sodium salt of carboxymethyl cellulose/acid clay = 31.0/54.0/10.0/5.0

Each pellet of the gas generating agent having a hollow cylindrical shape had an outside diameter 2.35 mm, inside diameter of 0.69 mm and a length of 3.0 mm.

Linear burning velocity under pressure of 70 kg/cm<sup>2</sup> was 11 mm/sec

The total surface area A of the pellets of the gas generating agent was 56804 mm<sup>2</sup> (37g).

The ratio (A/At) of the total surface area A of the gas generating pellets to the total opening area At of the gas discharge ports was 502.

"Evaluation"

The evaluation on the results of the tank pressure tests shown in Fig. 7 indicates that where A/At is equal to 502 as in the above example, a difference between the maximum pressures in the tank at 85°C and 20°C is about 30 kPa, and a difference between the maximum pressures in the tank at 20°C and -40°C is about 20 kPa. Thus, the differences between the maximum tank pressures at 85°C and 20°C, and at 20°C and -40°C are smaller than 40kPa, which means that operating characteristics of the gas generator are less likely to be influenced by changes in the temperature of the atmosphere.

And a difference between the maximum pressures in the tank at 85°C and 20°C and a difference between the maximum pressures in the tank at 20°C and -40°C are each 25 % or less of the maximum output pressure (about 160 kPa) in the tank test at 20°C.

The invention being thus described, it will be obvious that the same way may be varied in many ways. Such variation are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A gas generator for an air bag, comprising: a housing having at least one gas discharge port; igniting means that is actuated when an impact sensor detects an impact;

solid bodies of gas generating agent that are ignited by the igniting means and burned to generate a combustion gas; and coolant/filter means for cooling the combustion

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gas and scavenging combustion residues, said igniting means, said gas generating agent and said filter means being accommodated in said housing, wherein

a ratio (A/At) of a total surface area A of said solid bodies of gas generating agent to a total opening area At of said at least one gas discharge port is limited to be larger than 300.

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2. A gas generator for an air bag according to claim 1, wherein a difference between the maximum pressures at 85°C and 20°C and a difference between the maximum pressures at 20°C and -40°C obtained in tank pressure tests using a tank whose capacity is 60 l are each 25 % or less of the maximum output pressure in the tank pressure test at 20°C.

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3. A gas generator for an air bag according to claim 1, wherein

a difference between maximum pressures at 85°C and 20°C and a difference between maximum pressures at 20°C and -40°C obtained in tank pressure tests using a tank whose capacity is 60 l are respectively not higher than 40kPa.

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4. A gas generator for an air bag according to claim 1, wherein said gas generator is used for at least one of a driver side and a passenger side, and, said ratio (A/At) is larger than 300 and not larger than 1300.

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5. A gas generator for an air bag according to claim 1, wherein said gas generator is used for at least one of a driver side and a passenger side, and said ratio (A/At) is in a range of 450 to 1300.

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6. A gas generator for an air bag according to claim 1, wherein said gas generator is used for at least one of a driver side and a passenger side, and said ratio (A/At) is in a range of 450 to 1000.

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7. A gas generator for an air bag according to claim 1, wherein the total opening area At of said gas discharge port is in a range of 50 to 200 mm<sup>2</sup> where the gas generator is used for an air bag for a driver side, and is in a range of 60 to 500 mm<sup>2</sup> where the gas generator is used for an air bag for a passenger side.

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8. A gas generator for an air bag according to claim 1, wherein the total surface area A of said solid bodies of gas generating agent is in a range of  $4 \times 10^4$  to  $7 \times 10^4$  mm<sup>2</sup> where the gas generator is used for an air bag for a driver side, and is in a range of  $6 \times 10^4$  to  $3 \times 10^5$  mm<sup>2</sup> where the gas generator is used for

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an air bag for a passenger side.

9. A gas generator for an air bag according to claim 1, wherein each of said at least one discharge port has an inside diameter of 2 to 5 mm. 5

10. A gas generator for an air bag according to claim 1, wherein said solid bodies of gas generating agent have a linear burning velocity of 7 to 30 mm/sec under a pressure of 70 kg/cm<sup>2</sup>. 10

11. A gas generator for an air bag according to claim 1, wherein said solid bodies of gas generating agent have a linear burning velocity of 7 to 15 mm/sec under a pressure of 70 kg/cm<sup>2</sup>. 15

12. A gas generator for an air bag according to claim 1, wherein said gas generating agent is a non-azide gas generating agent containing a nitrogen containing organic compound, an oxidizing agent, and a slag-forming agent. 20

13. A gas generator for an air bag according to claim 12, wherein said gas generating agent contains 25 to 60% by weight of the nitrogen containing organic compound, 40 to 65% by weight of the oxidizing agent, and 1 to 20% by weight of the slag-forming agent. 25

14. A gas generator for an air bag according to claim 12, wherein the nitrogen containing organic compound is nitroguanidine. 30

15. A gas generator for an air bag according to claim 12, wherein the slag-forming agent is acid clay. 35

16. A gas generator for an air bag according to claim 1, wherein each of said solid bodies of gas generating agent is formed into a cylindrical shape having a single hole. 40

17. A gas generator for an air bag according to claim 1, wherein an amount of said gas generating agent loaded in the gas generator is in a range of 20 to 50g where the gas generator is to be used for an air bag for a driver side, and in a range of 50 to 190g where the gas generator is to be used for an air bag for a passenger side. 45

18. A gas generator according any one of Claim 1, wherein the value of a pressure loss of said filter means is lower than the value of a pressure loss of the gas discharge ports formed in the housing. 50

19. An air bag system comprising: 55

a gas generator for an air bag,  
an impact sensor that actuates the gas genera-

Figure 1

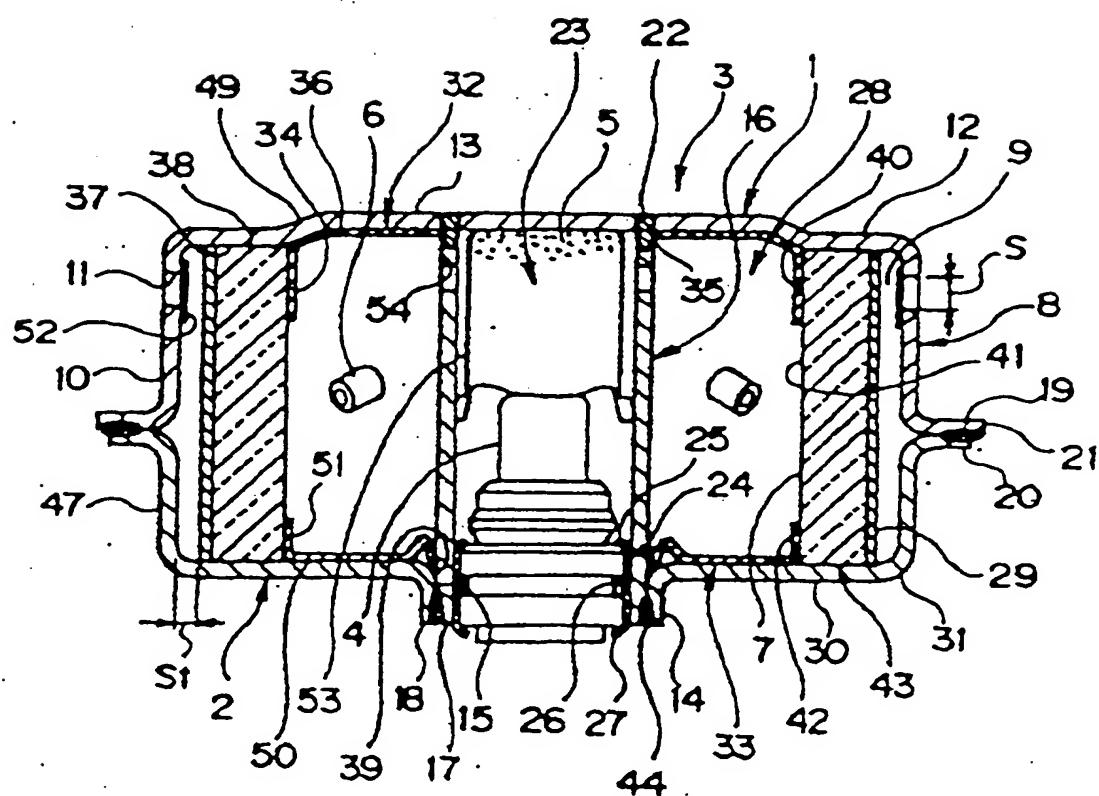


Figure 2

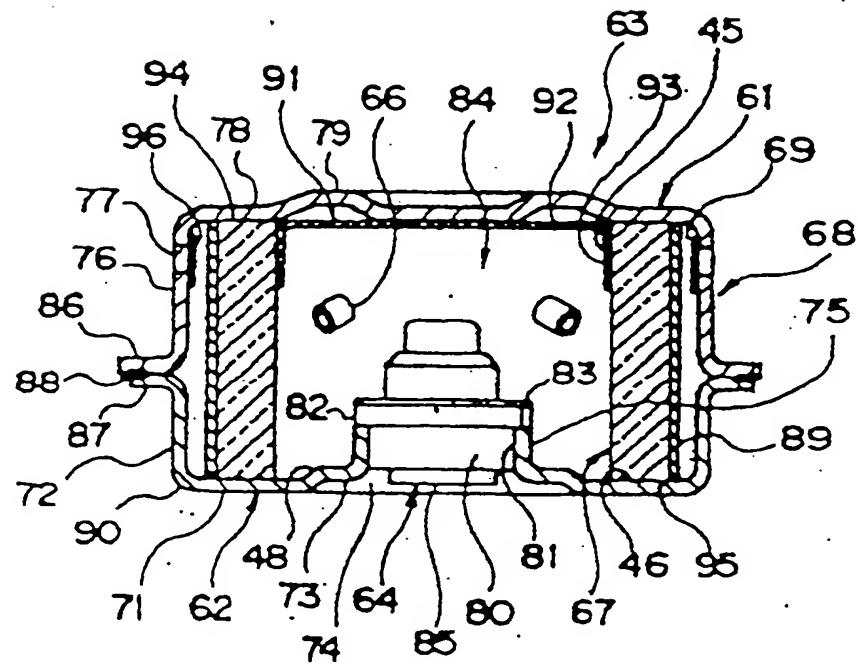


Figure 3

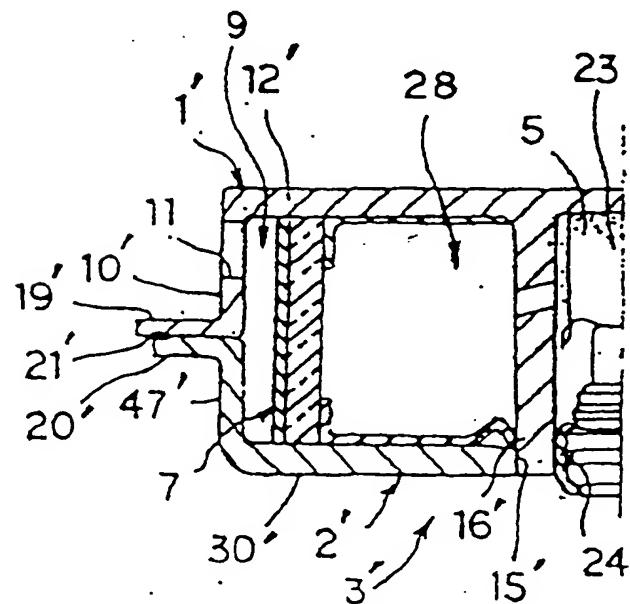


Figure 4

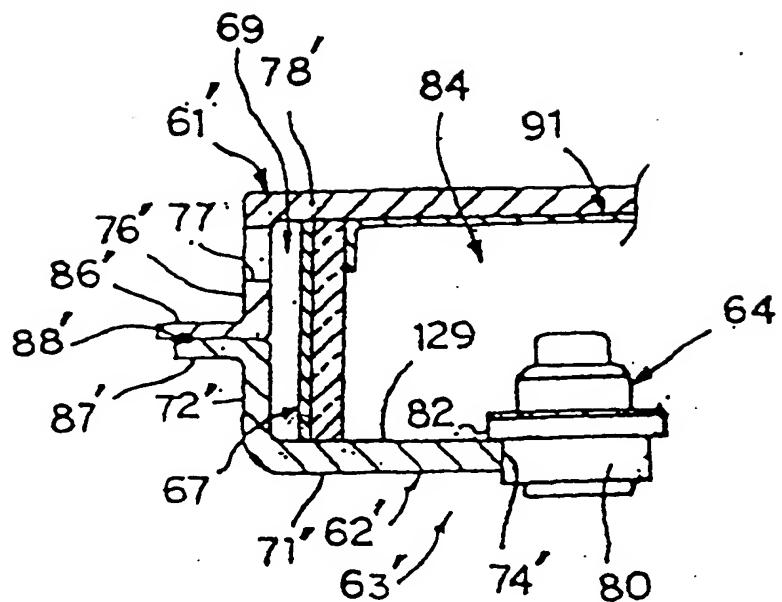


Figure 5

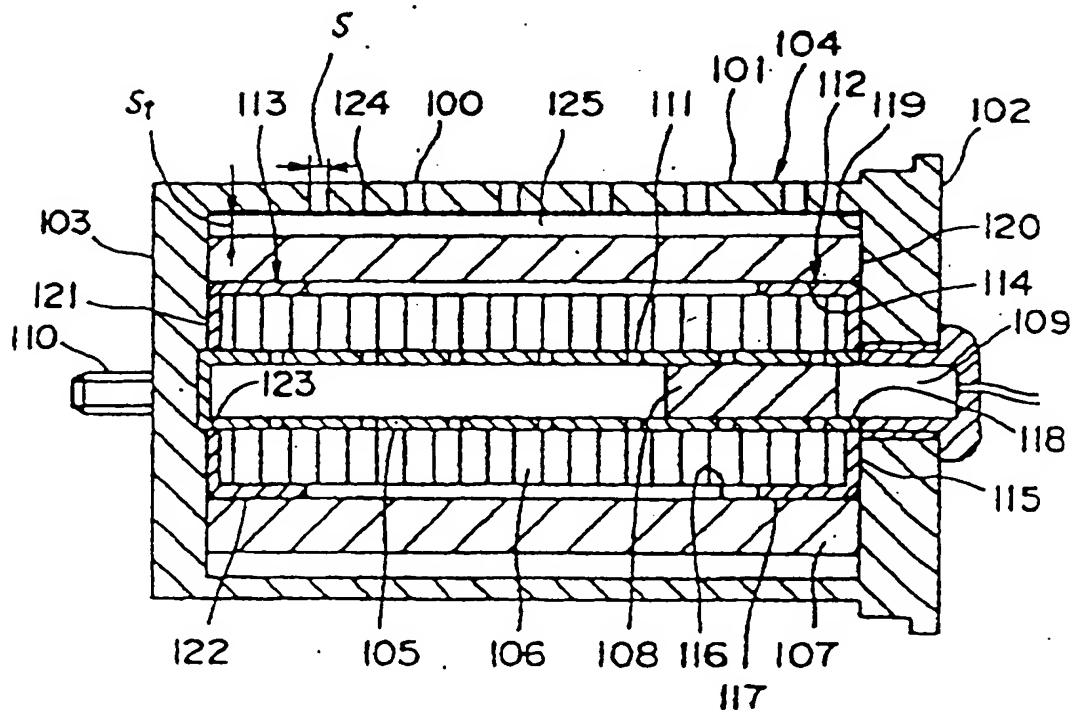


Figure 6

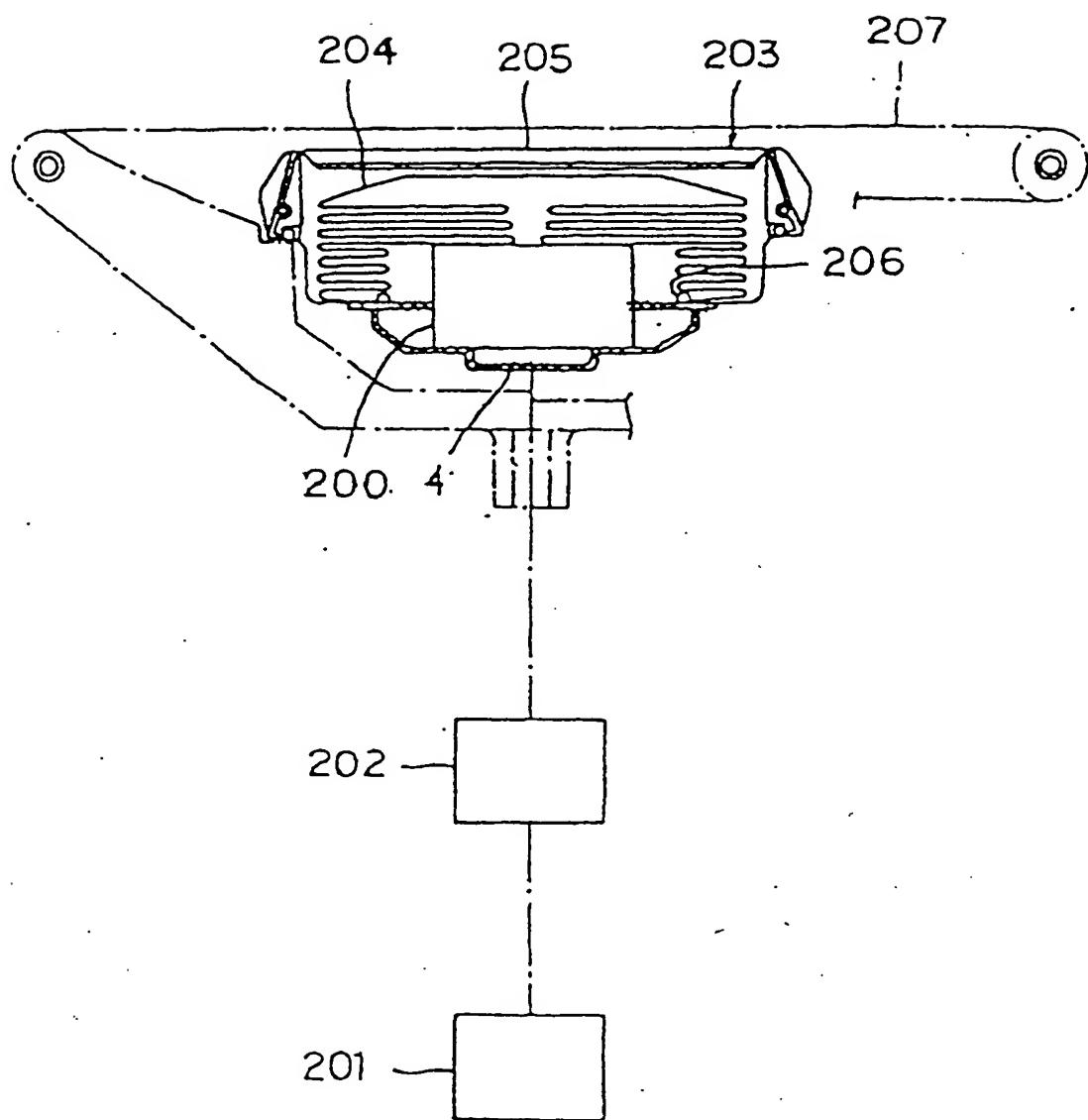


Figure 7

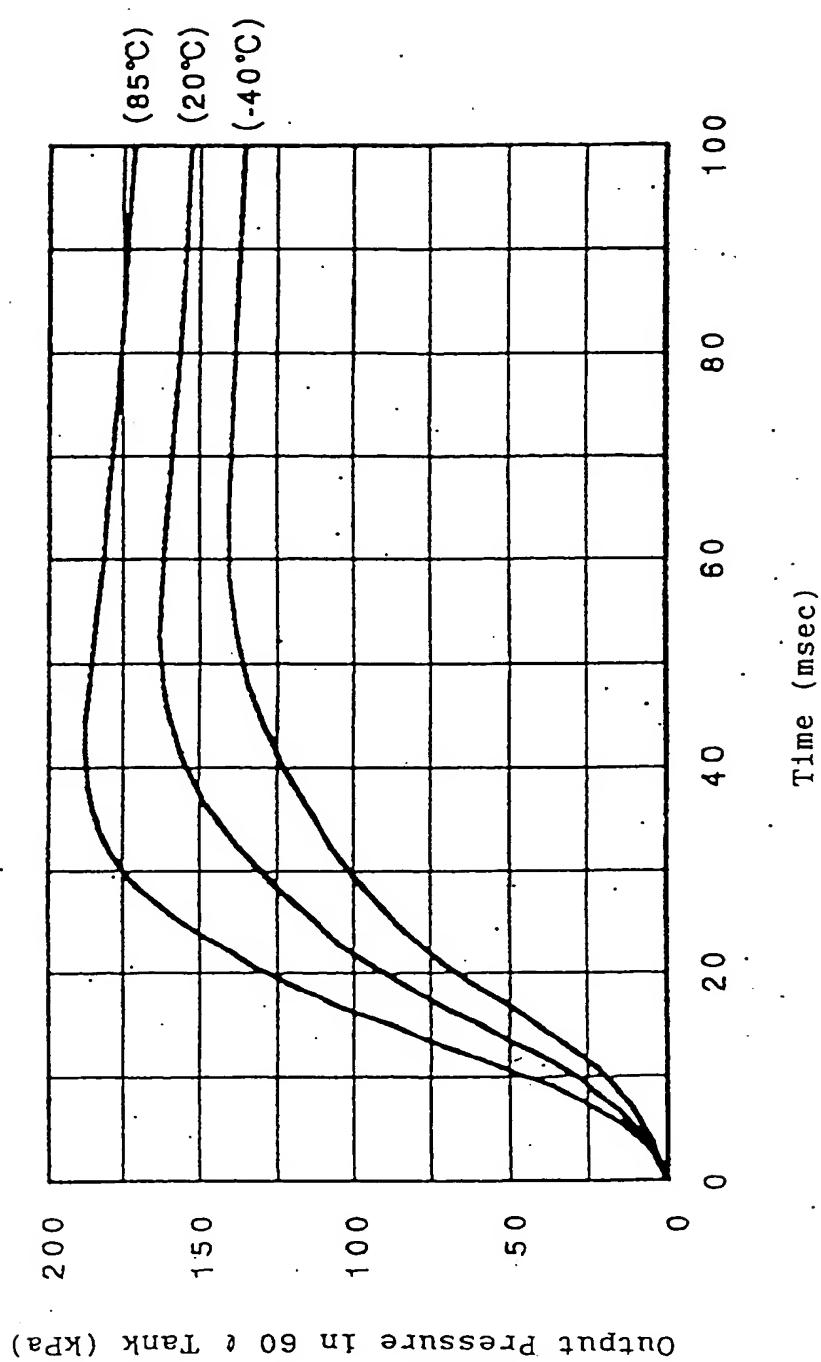


Figure 8

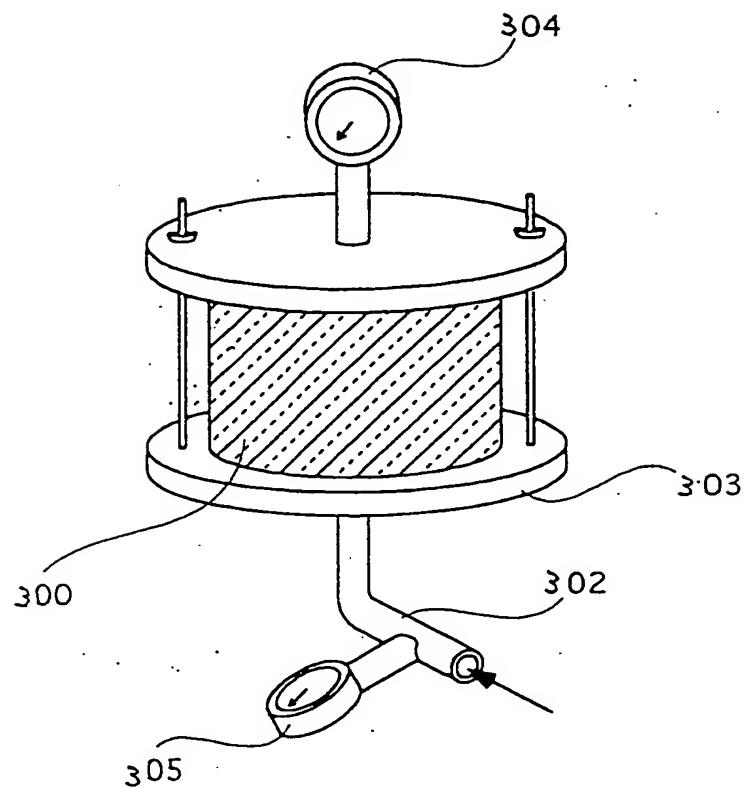


Figure 9

